Experimentation with Evolving C2 Operation Centers – Implications for the Human Element

Mr. Michael Goodman, Mr. Michael Garrambone,
and Mr. Evan Rolek
Veridian Engineering
5200 Springfield Pike, Suite 200
Dayton, OH 45431-1289

Capt Ed McCormick
AFRL/HEAI
Brooks AFB, TX

Abstract

In spite of the surge in new technologies, complex operational processes, and high operations tempos, the selection, education, training, and team functions of the modern C2 operators has not been given comparable attention. In order to properly staff future C2 operations centers with capable individuals and operational teams, attention needs to be directed to the analysis of the evolving C2 operator training requirements and team dynamics that are being driven by modern technology and changing concepts of operations.

This paper will describe the assessment approach and methodology employed by the Air Force Research Laboratory's Warfighter Training Research Division, Information Systems Training Branch, Brooks AFB, TX (AFRL/HEAI) researchers as they observed the C2 operators in the Time Critical Targeting Cell (TCTC) during Joint Expeditionary Force eXperiment 2000 (JEFX 00). The AFRL/HEAI researchers followed a human-factors oriented approach in developing a data collection methodology to gain insight into the scope of issues confronting personnel in modern C2 operation centers. This approach stressed the importance of C2 functions and processes related to time critical targeting that depended on the interactions among individuals and teams of C2 operators. These insights may ultimately assist in the specification of C2 operator training requirements and help characterize the individual and team "desired" performance capabilities.

SECTION 1.0
INTRODUCTION

1.1 Background

As a result of similar interests in conducting research and experimentation with Air Force Command and Control (C2) processes, AFRL/HEAI volunteered the services of several of its research staff to assist in the assessment of C2 issues during the JEFX 00JEFX 00 evolutionary activities. The JEFX 00 activities the AFRL/HEA team members participated in included three spiral development events and the main JEFX 00

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
JUN 2001		**00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Exerimentation with Evolving C2 Operation Centers - Implications for the Human Element	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Veridian Engineering,5200 Springfield Pike Suite 200,Dayton,OH,45431-1289**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**25**	

experiment. The JEFX 00 events occurred during various periods between 15 March and 15 September 2000. Assessments of the TCTC Process Initiative were accomplished by the team members during Spiral 2, 3 and the Main Experiment at Nellis AFB, Nevada. The AFRL/HEAI analysts, as members of the AFEO Assessment Team, were tasked to collect and provide information on organizational processes and interfaces and to examine and provide descriptive measures from a human factors perspective in the areas of communications patterns, personnel, and team work. In addition, the team was asked to look at organization and leadership from the Doctrine, Organization, Training, Materiel, Leadership, and Personnel (DOTMLP) perspective and provide this information in a form most useful to the warfighter.

1.2 Scope

Due to the high visibility of the JEFX 00 experiment, the competing objectives of numerous Air Force Agencies, and the associated environmental constraints, only three research analysts were permitted to take part in each of the spiral and Main Experiment events. The research analysts designed measures of merit and data collection forms of various formats to garner raw operational data and record individual observations. The analysts spent their entire time collecting information and recording the comments and ideas expressed by TCT Cell members for more than 35 days of activities encompassing the three spirals and the high intensity period of the Main Experiment.

1.3 Experiment Overview

The Joint Expeditionary Force eXperiments provide the Air Force with a vehicle for experimentation with operational concepts and technologies that will enhance aerospace capabilities in the 21st century. JEFX 00 is the third in a series of large-scale Air Force experiments. Previous Joint Expeditionary Force eXperiments were conducted in 1998 and 1999. EFX '98 was the Air Force's first large-scale experiment and explored the ability to move information while deploying fewer people and less equipment. JEFX '99 built upon the lessons learned in the '98 experiment to better integrate space personnel and resources into the expeditionary aerospace operations. JEFX 00 focused on agile combat support and time-critical targeting that will provide an enhanced capability to the Joint Force and the Combined Forces Air Component Commander (CFACC).

JEFX is not an exercise, test, or technology demonstration. The JEFX process is a discovery process that integrates new and emerging technologies, solves deficiencies, and provides advanced capabilities. The main point of these experiments is to learn and discover new and improved methods and processes for conducting military operations, not to train. These experiments are designed to involve the warfighters early in the development of new concepts and technologies. This process allows the Air Force to provide more operationally focused systems and processes necessary to reach Joint Vision 2020.

The main objectives for JEFX 00 were to explore improvements in global mobility; intelligence; surveillance and reconnaissance battle management; and a new concept that allows data to be turned into information for our warfighters – the Joint Battlespace Infosphere. To this end, JEFX 00 examined 45 processes and system initiatives with a supporting cast of more than 3,000 military participants at 11 sites across the nation. JEFX 00 combined the use of models, simulations, and live-fly operations.

The three main operating locations for JEFX 00 were Langley AFB, VA, Hurlburt Field, FL, and Nellis AFB, NV. Located at Langley AFB was the Operations Support Center (OSC) where many of the "reach-back" and agile combat support functions were explored. The Combined Air Operations Center-Rear (CAOC-R) was located at Hurlburt Field. The CAOC-R was the node from which the CFACC developed and promulgated theater objectives. Located at Nellis AFB was a secured compound that was designated the Combined Air Operations Center-Forward (CAOC-F) which contained a Time Critical Targeting Cell (TCTC). A macro view of the participant nodes and organizations is depicted in Figure 1-1. The AFRL/HEAI personnel were located at Nellis AFB and served inside the TCTC as part of the AFEO Assessment Team. The scope of the AFRL/HEAI JEFX 00 assessment is limited to the TCTC process initiative in the CAOC-F conducted at Nellis AFB.

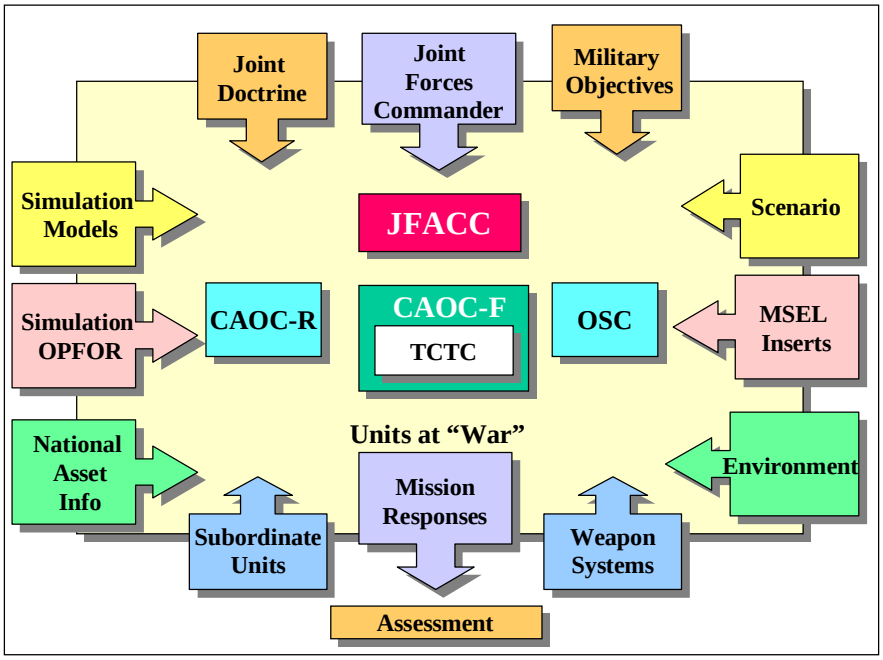


Figure 1-1 The "Big Picture" of JEFX 00 influences and nodes

Prior to the Main Experiment, there were many days of spiral rehearsals to work out the integration of systems and the operational procedures needed to accomplish the Time Critical Targeting mission. Each spiral provided analysts the opportunity to see the evolution of operator procedures, team processes, and gain experience with prototype systems. The final experiment consisted of additional operator training, process and technology practice, simulation, and live-fly periods.

During the Main Experiment, virtual and constructive simulation and live-flying operations were employed. The TCT Cell at Nellis AFB, Nevada was part of the Combined Air Operations Center (CAOC) Forward with the CAOC-Rear at Hurlburt Field, FL and the Operations Support Center (OSC) located at Langley AFB, VA.

A scenario that allowed for time-critical targets to "emerge" drove each day of the experiment. The targets had to be detected using ISR assets, prioritized, coordinated with the CAOC for a destruction decision, and committed on by the appropriate and available weapon assets. The air battle management section controlled the assigned attack platform(s), and the target was assessed for battle damage through aircrew reports and tactical and national ISR assets. All of these activities were accomplished by the TCT cell, which consisted of a Command Section, Hunter Section, Killer Section, datalink Interface Control Section, and Joint Battlespace Infosphere Management Section. The mission of the assessment team was to observe these teams in action and derive as much information about their activities and processes as possible.

1.4 Assessment Participants at Nellis AFB

Government military, civilian, and contractor personnel from around the country supported the assessment of the technology and processes evaluated in the TCTC at Nellis AFB. In addition to the three AFRL/HEAI assessment personnel, there were numerous contractors from multiple companies who were assigned to the TCTC Assessment Team. The Nellis AFB TCTC Assessment Team included representatives from Air Combat Command (ACC), the Aerospace Command and Control, Intelligence, Surveillance & Reconnaissance Center (AC2ISRC), the Command and Control Training and Innovation Group (C2TIG), 1st Air Force, and the 552 Air Control Wing.

The AFRL/HEAI Command and Control Training Research (C2TR) assessment team was able to orchestrate having a number of its members attend portions of the various JEFX 00 events. At an assortment of times during the three Spirals and the Main Experiment, the C2TR personnel listed in Figure 1-2 had the opportunity to attend the specified JEFX 00 activities.

Name	Organization	Activities Attended
Capt. Ed McCormick	AFRL/HEA C2TR Program Manager	Spiral 1, 2, and 3
Mike Garrambone	Veridian Engineering	Spiral 3, ME
Matt Dalrymple	Veridian Engineering	Spiral 2
Debbie Hall	Veridian Engineering	Spiral 3
Mike Goodman	Veridian Engineering	Spiral 1, 2, 3, ME
Mike Paley	Aptima Inc.	Spiral 1, 2, ME
Sarah Miescher	Aptima Inc.	Spiral 1, 3
Spiral 1 – C2 Unified Battlespace Environment (CUBE), Hanscom AFB, 15-22 Mar '00 Spiral 2 – Nellis AFB, 30 May – 9 Jun '00 Spiral 3 – Nellis AFB, 3-13 Aug '00 Main Experiment (ME) – Nellis AFB, 28 Aug – 15 Sep '00		

Figure 1-2. AFRL/HEA C2TR Team's Participants in JEFX 00

1.5 Experimental Matrix for JEFX 00

Although JEFXs are designed and referred to as experiments, they are actually not experiments in the classical, scientific, or statistical sense. These experiments are much too complex to boil down to the investigation of one or two variables that can be evaluated to accept or reject a hypothesis. The JEFX experiments have hypotheses, but they are addressed in a more qualitative vice quantitative manner. The experiments are not demonstrations. They have carefully considered specific measures of effectiveness. Unlike a demonstration, failure is acceptable--in fact, just as much can be learned from failure as from success. Consequently, the JEFX format is all about experimenting with new and innovative technologies and processes to discover improved ways to conduct military operations.

Because JEFX 00 was not a laboratory-controlled experiment in the classical sense, a standard statistical experimental design did not exist. There were, however, measures of effectiveness and performance applicable to desired assessment outcomes.

The JEFX 00 Initiatives were assessed from five perspectives which included technical, warfighter utility, thread assessment, joint capabilities level, and experimentation management. The technical assessment was completed by the Electronic Security Center prior to JEFX to ensure each initiative technically worked. The warfighter utility assessed the utility of the initiative in performing operational tasks. The thread assessment incorporated the evaluation of how well multiple initiatives

worked together in support of a specific area of responsibility. The joint capabilities level assessment involved determining whether the initiatives have Joint applications and did it aid the JFACC/JTF in accomplishing Joint tasks. Experiment management was also evaluated to assess whether improvements could be made in planning, designing, executing, and assessing the JEFX experiments.

SECTION 2.0
AFRL/HEAI'S INTEREST IN JEFX 00

2.1 AFRL/HEAI APPROACH

The Information Systems Training Research Branch, as a focused research arm of the Air Force Research Laboratory, has a vested interest in helping to assess and characterize the multitude of activities that collectively comprise the Air Force command and control (C2) process. There is currently a revolutionary atmosphere that is driving a comprehensive review of the way the Air Force has historically conducted C2 operations. In keeping pace with this revolution, the JEFX experimentation test bed has created an excellent venue for assessing not only the new technology of the future, but also the role of the human element in the facilitation and management of the overall C2 processes.

Twenty-first century warfare has mandated the need to integrate orders of magnitude more information sources provided by new sensors to develop a coherent picture of the battlespace and to formulate C2 responses in a distributed environment. Today, C2 operators are required to manage larger and larger quantities of battlespace information, and to do it more quickly in situations that are unlike those of former ages. An assessment of the role of the human element within this new and evolving C2 environment is needed to help determine the selection of the optimum type of individuals to serve in these C2 operation centers. Equally important is the evaluation of the changing role of team functions/processes, and the implications of operator workload levels including psychomotor and cognitive loads, etc. AFRL/HEAI, therefore, proposed accomplishing a human factors-oriented assessment of the human element within and throughout the TCTC experimentation processes as part of the JEFX Assessment Integrated Process Team.

The primary purpose for AFRL/HEAI's interest in the JEFX 00 environment was to gain insight into the scope of modern issues that are driving the C2 operator training requirements. AFRL/HEAI CTR's goals are to provide the best technology, methods, and processes to train the modern warfighters. The C2TR team members are concentrating on the C2 operator training needs and the best means to train them faster, better, and cheaper.

The data for this assessment was gained through observation of the JEFX 00 C2 operator teams in the performance of their duties and through consultation with operators, as appropriate, on a non-interference basis. All output from the AFRL/HEAI assessment was and will continue to be coordinated through the Air Force Experimentation Office.

The AFRL/HEAI assessment team was comprised of three C2TR analysts who possess human factors and C2 subject matter experience and expertise.

The AFRL/HEAI personnel represented the training-research component of the assessment team. Although the first obligation was to support the assessment requirements of the AFEO Assessment Team, the AFRL/HEA representatives brought a different perspective to evaluation of the activity occurring in the TCTC at Nellis AFB. The primary interests of the AFRL/HEAI researchers included the communication and information flows, the team building and interaction activities, coordination processes, information management, leadership, operator training and other human factor issues.

The analysts integrated with and supported the Assessment Branch to assist in assessment of the Time Critical Targeting Cell Process Initiative conducted at Nellis AFB. Although the primary AFRL/HEA "going-in" focus was on team interactions, training, and communications patterns, AFEO requested that the AFRL/HEA team look at drawing some conclusions on leadership and people without "evaluating" individual or group performance.

2.2 133rd Air Control Squadron

Previous work with the 133rd Air Control Squadron (133rd ACS) Ft. Dodge, IA was a contributing factor that influenced AFRL/HEAI's desire to participate in JEFX 00. The 133rd ACS, as a Control and Reporting Element (CRE) of the ground-based Theater Air Control System (GTACS), had been helpful in providing AFRL/HEAI with insight into the roles, functions, and missions of the GTACS C2 operators. The surveillance, weapons, and battle management C2 operators from the 133rd ACS had provided a lot of useful information to AFRL/HEAI analysts investigating the operator training challenges in these types of C2 organizations. However, AFRL/HEAI's desired research scope encompassed not only the in-garrison CRE C2 operator functions but also those additional functions performed when connected to a netted theater architecture. In addition, AFRL/HEAI's goals included research on the C2 operator training requirements from all theater C2 nodes.

In light of AFRL/HEAI's desires to observe other C2 nodes as well as the 133rd ACS in a netted environment, the 133rd ACS encouraged the AFRL/HEAI's C2TR team to observe them during JEFX 00. The purpose of the observation would be to gain additional insight and to also assist the 133rd ACS by providing them with an objective and credible assessment of their performance during time-critical targeting operations. Because the 133rd ACS provided the strike control and overall target execution functions in the TCTC during JEFX 00, observation of their varied C2 tasks was deemed by C2TR analysts as a desirable activity to pursue. As a direct result of the invitation by the 133rd ACS, the C2TR team sought appropriate avenues for integrating into the JEFX 00 TCTC operation.

SECTION 3.0
ASSESSMENT METHODOLGY

3.1 Human Factors Considerations

The purpose of this section of the report is to document the human factors considerations used to develop the data collection methodology, which ultimately influences the analysis, interpretation, and conclusions from this exercise. In the interests of brevity, some brief background will be provided but the emphasis will be on the major issues.

The time critical targeting process is being enhanced through the parallel efforts of technology application and human operator methodology. This approach yields greater synergism than an approach that focuses exclusively on hardware/software or crew organization/training individually. The parallel approach is driven by the nature of the changing operational environment for time critical targets including:

1. Vastly increased quantities of data and information including imagery from localized and national assets.
2. Reduced time available for prosecuting time critical targets such as Scuds/TELs, SA-10C, SA-15, etc.
3. Evolving roles for individuals and teams within the C2 decision structure.

Based upon the above considerations, Veridian Engineering supported AFRL/HEAI with developing a crew-centered approach for conducting an assessment during JEFX 00. This approach stressed the importance of C2 functions and processes related to time critical targeting that depend on interactions among individuals and teams. As a result, the most significant issues that were addressed included workload, cognitive load, individual and team processes, information flow, and decision making. The intent was to use JEFX 00 to obtain insights for shaping efforts to (1) optimize the architecture of various C2 organizations, and (2) develop training research facilities and methodologies used to enhance crew performance. The context of data collection influenced the allowable methodology options as well as the interpretation and conclusions that were drawn from the data that was obtained from this experiment.

The concepts that form the basis for Figure 3-1 can be used to envision some generalized relationships among the data collection context and several factors associated with data capture, data reduction, data analysis, and formulating conclusions. To use the figure, one can select a “context region” that represents the approximate operating region for data collection. The center of the figure relates the general context breadth over which studies can be conducted. For any given context selected, one can draw an imaginary line both above and below this region to determine various implications for the study based upon the context. Although not shown in the figure, JEFX 00 was envisioned as being between the “middle ground” and the right hand side of the figure.

In other words, the context was one of a field exercise where crew decision making has been labeled as "naturalistic" by some authors; this means that highly trained operators used actual hardware and software for realistic decision making according to a combat-like event flow for time critical targets. This is in contrast to "the left side" of the context region, laboratory environments studying classical decision making, where it is common to use college sophomores as subjects, with simulated hardware and software used for making simplistic decisions with an artificial event flow. Understanding the context of the study allowed the project team to optimize the data collection methodology and understand the bounds of data processing.

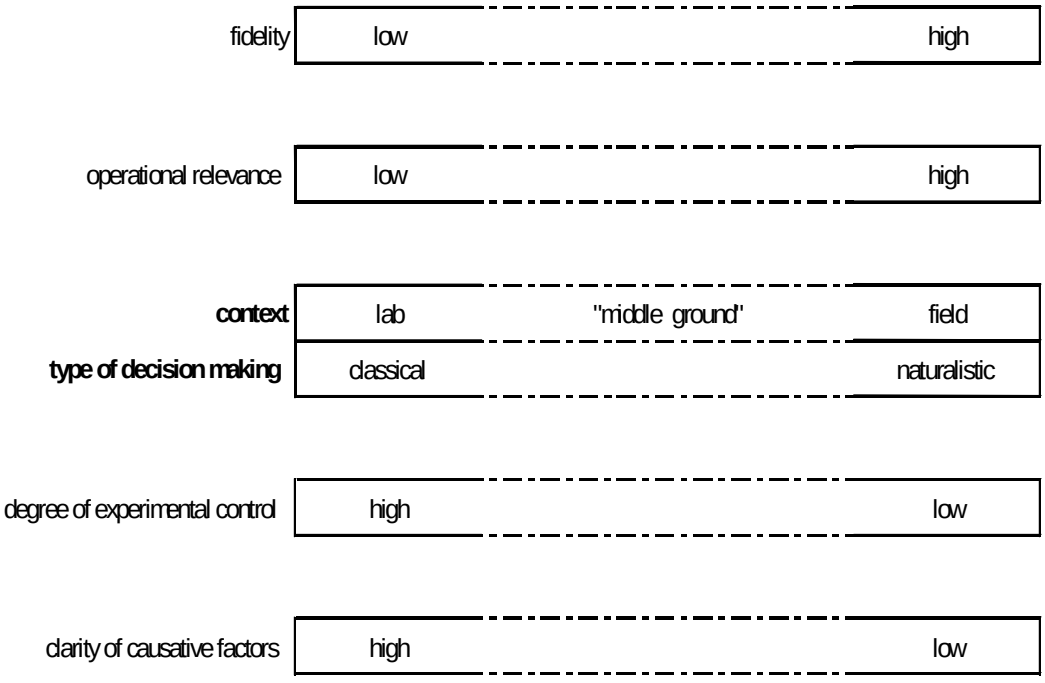


Figure 3-1. Context vs. Science

The term "fidelity" in the figure relates primarily to functional fidelity which has to do with the realism of the functions and tasks performed by the C2 crew and not merely physical or face validity where the appearance of the support hardware is the issue. Due to the nature of JEFX 00, it was generally agreed that we were to operating in a fairly realistic context. This has the side benefit of affording high "operational relevance" because the what, when, why, and how of C2 decision making were very much like combat operations for time critical targeting. Focusing on the lower portion of Figure 3.1 one can assess the degree of experimental control implied by the respective context. Laboratory environments lend themselves to very high degrees of control, what factors are held constant, and which are allowed to vary. As one moves to the right toward field studies, there is less control based upon various practical constraints; this starts to approximate the "fog of war" where uncontrolled factors can be quite numerous and influential. This lack of control does not invalidate the findings from operational

contexts, but it does place a requirement on recording factors surrounding the event flow so that one has some insights about influences to the results. These influences, or causative factors as shown on the figure, are clearer in a laboratory context because so many factors are held constant and only a limited number are varied over a given range. The reverse is true in field contexts because it is not possible to precisely control large numbers of factors to the degree that one can in a laboratory setting. Hence, the more factors that are allowed to vary, the more competing causes exist for explaining or confounding the results. These competing causes may exert influence individually or may interact with each other in complex ways.

Although not shown in the figure, there are additional factors that are strongly related to the choice of context and include number of crewmembers, number of replications, and measures of effectiveness. On one end of the spectrum, for laboratory studies, it is often common to have from 20 to 100 or more subjects or teams based upon such practical factors as subject availability, scheduled time for data collection, and reimbursement costs. However, at the other end of the spectrum, for field studies, the practicalities of schedules for range time, availability of information and weapon systems, crew training, security, et cetera, often dictate that small numbers of replications for any given treatment condition of interest. Quite a few more replications are practical for laboratory settings and are often pursued to obtain stable data from a statistical perspective. In field exercises/experiments, such as JEFX 00, a replication of "1" is sometimes all that is practical. Note that it is not only more difficult to obtain a greater number of replications in field settings, it is also more difficult to control the data collection environment to ensure equivalency of treatment replications. There are too many factors that cannot be controlled in the field that are easy to standardize in laboratory environments. Examples include weather and visibility conditions, location of participants for the exercise, unexpected events, and compliance with rules of engagement. As will be shown, the above issues strongly relate to measures of effectiveness.

Laboratory studies typically entail the use of several measures of effectiveness and some studies have used very large number of measures. The number of measures is driven not just by practicalities of the instrumentation systems used to collect the data but also by the nature of the studies themselves. Exploratory studies will often measure a large number of (dependent) variables or measures as part of an overall effort to establish and understand relationships. Yet in other cases, there is a need to establish a performance database and hence large numbers of measures will likewise be obtained. The number of measures in laboratory settings has relatively few bounds because there is a desire to learn as much as possible in the interests of science and not necessarily what has immediate practical application; conclusively identifying causative or diagnostic factors is of great interest. As one deviates from laboratory environments and moves toward field exercises, there is a general trend toward fewer measures and the measures tend to be more descriptive than diagnostic, plus they shift from the crew task/function perspective to the engagement or mission level perspective. Field exercises tend to focus on using measures that have immediate operational relevance such as probability of kill, exchange ratios, or resources expended.

As used here, the term "measures" embodies three distinct yet related issues: (1) operational definition of measures, (2) criteria, and (3) standards. There is quite a bit of latitude in terms of how these issues apply to the various data collection contexts, but in the interests of brevity, only a cursory discussion will be presented here.

3.2 Measures

With regard to operational definition of measures, what is meant here is an overt statement of what is going to be measured, how, when, and to what resolution for each respective "measure." In some instances, there is also a need to define the processes associated with data processing. The topic of operational definition of measures is particularly critical with regard to human operator experimentation, such as JEFX 00, because there is so much misunderstanding operator/crew measures and some measures do not exist in reality, they are theoretical constructs. Unlike system or mission level measures such as number of targets prosecuted, number of assets utilized, or exchange ratios, crew/team measures such as workload, situation awareness, or leadership do not have "plug and play meters" that can be inserted into the system for automated data collection. Instead, there must be a description of what the theoretical constructs are in terms of what is measured, how, and when. For example, workload might be defined as an AWACS operator rating how much more difficulty it is to assign fighters to a target compared to merely monitoring the air situation; the task might be rated as twice as difficult, three times as difficult, and so forth.

Specifying specific criteria is an issue that applies to all measures, those that are crew-centered as well as others. For example, a mission level measure might be survivability. An associated criterion might be number of AAA rounds hitting an aircraft. Some criteria have established credibility due to longstanding use in the laboratory through field contexts while others have been newly developed and must be used with caution.

Then there is the topic of standards that refers to an agreed upon or decreed value of a given criterion. For example above, a standard might be "if 5 AAA rounds hit an aircraft, it is considered a kill." Standards are not as common for crew-centered measures, however. Many of the reasons for this are due to the fact that quantifying "the human system" is vastly more complex than for other physical systems. The relationship between crew performance and system performance is not always clear cut. For example, an AAA gunner might be exposed to the same target aircraft twice in succession. One time the gunner might rate the engagement as difficult and achieve a low to moderate probability of kill, while the second time the gunner might also rate the engagement as difficult yet achieve a high probability of kill. So using a rating of "difficult" as a standard is not as straightforward as one might hope. Sometimes the project team relies on relative comparisons such as "system A is easier to use than systems B and C" due to the lack of an agreed –upon standard.

For JEFX 00, as related to time critical targeting from the crew perspective, there were several considerations that strongly influenced the data capture methodology that was developed. These considerations were:

1. JEFX 00 was more of an operational exercise than a test and evaluation study.
2. Complete and accurate knowledge of the truth set might not be readily available for the entire exercise.
3. Crewmembers, while all could be expected to be highly trained, cannot be individually selected, may be rotated during JEFX 00, and could occasionally be substituted with replacements.
4. Interactions among crewmembers or with external organizations are at the discretion of the crewmembers and are not under the control of observers.
5. There should be an attempt to assess crew-centered issues at the task, function, and mission levels yielding quantitative and qualitative data.
6. Automated instrumentation is unavailable.
7. While data capture can be obtrusive, it must not be invasive.

3.3 Assessment Methodology Tools

The AFRL/HEAI assessment team employed a proven subjective assessment tool to quantify information and communication flow within an organization during Spiral 3 and the Main Experiment of JEFX 00. Aptima, Inc. had successfully utilized these same data collection methods during the US Navy's Global 2000 exercise and operator-in-the-loop experiments. These measurement techniques were designed to focus on interactions and events that are critical to organizational effectiveness and provide insight into how team interaction develops over time. This data collection was designed to be tied to critical mission events and addresses multiple aspects of the organizational process. As new information regarding a critical event is injected into an organization (i.e., identification of a new hostile threat), specific data is collected to assess how this information is managed and transmitted throughout the organization, and how it is employed for mission execution. For JEFX 00, the AFRL/HEAI's C2TR objective was to focus data collection on communication and information flow within the TCTC.

In order to employ these data collection methods to their full capacity, access to all forms of communication within the organization must be obtained. To accomplish this, in previous exercises, the data collection team comprised about half of the operational organization. Large numbers of data collectors are needed to capture complete information flow. The AFRL/HEAI assessment team was limited to three people for Spiral 2, Spiral 3, and the Main Experiment. As such, a decision was made to

focus on "key" leadership positions in three sections (i.e. Director 1 and 2 in Hunter Section, Sniper Lead in Sniper Section and the MCC in Slayer Section).

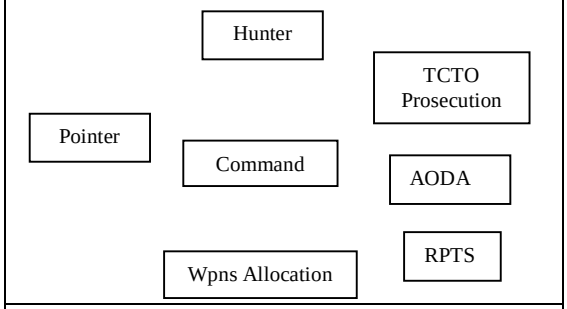
The three observers stationed themselves within the TCTC and collected interaction data focusing on information flow, communication patterns, teamwork assessment, coordination, and information management. Data collection, however, proved more difficult than in previous implementations due to limited access to all forms of communication. Data collectors had access to internal radio communications but intermittent access to the external links used by Slayer to conduct battle management. Monitoring text chat proved difficult because of the size of the font and our positioning next to or behind the operators. Overall, the data collectors were able to obtain enough data to make a variety of analytic assessments, but future data collection may require additional personnel to capture the complete range of interactions or a narrower collection focus must be defined.

3.4 Sample Data Collection Material

The C2TR assessment team developed both paper and computer-based data collection tools, however the computer-based tools were not allowed into the compound due to security issues. Therefore, only the paper and pencil data collection booklets were used during JEFX. Originally, to capture team interactions and information flow, the following Figures (or sheets) were used during Spiral 3. In Figure 3-2 the observer was to draw an arrow to indicate the communication flow (from section to section), and take copious notes about the communication (e.g. types of communications such as requests for information, clarification, etc.). The more notes that could be captured on the communications enabled better reconstruction of the events.

Figure 3-2 provided observers with a means to record communications patterns within the individual TCTC sections. Figure 3-3 helped observers characterize the types of communications that took place.

Observer _____ **Start** _____ : _____
Date _____ **Finish** _____ : _____



Initiatives

Ad-Hoc Groupings

Key Events

Figure 3-2. Layout of Team to Capture Team Interactions and Information Flow

Observer _____ **Start** _____ : _____
Date _____ **Finish** _____ : _____

Information going OUT

Put a 0 to indicate where you are located. Rank order the others to indicate to which area the most information is sent (1=most; 6=least)

AREA	RANK	AREA	RANK
Hunter …….....	_____	AODA……	_____
Pointer……...	_____	RPTS……..	_____
Command……..	_____	TCTO Prosecution…..	_____
Wpns Allocation….....	_____		

- Check three items below that best characterize the nature of information sent by your cell.

❑ Orders	❑ Info to subords	❑ Intel updates
❑ RFI	❑ Info to HHQ	❑ Collaborate on products
❑ Clarification	❑ Situation updates	
❑ Info to peers	❑ Logistic updates	❑ Synchronization
❑ COA analysis	❑ Nominate targets	❑ Confirmations

Information coming IN

Put a 0 to indicate where you are located. Rank order the others to indicate to which area the most information is sent (1=ost; 6=least)

AREA	RANK	AREA	RANK
Hunter …….....	_____	AODA……	_____
Pointer……...	_____	RPTS……..	_____
Command……..	_____	TCTO Prosecution…..	_____
Wpns Allocation….....	_____		

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❑ Clarification	❑ Situation updates	
❑ Info to peers	❑ Logistic updates	❑ Synchronization
❑ COA analysis	❑ Nominate targets	❑ Confirmations

Figure 3-3. Questionnaire on the Evolution of the Communication Patterns of the Team

This method of data collection proved to be rather cumbersome as there were many pages to content with plus there was so much activity audibly and visually that it was a supreme challenge to try to keep up with and record everything. It was actually an impossible task for only three analysts to capture all that was occurring in an operations cell occupied by more than 65 people at any given time.

The observers also made use of the Teamwork Assessment Questionnaire Forms to comment on the different aspects of teamwork activities. Figure 3-4 guided observers to assess teamwork issues such as team coordination, communication, monitoring tasks, back-up tasks, and team orientation.

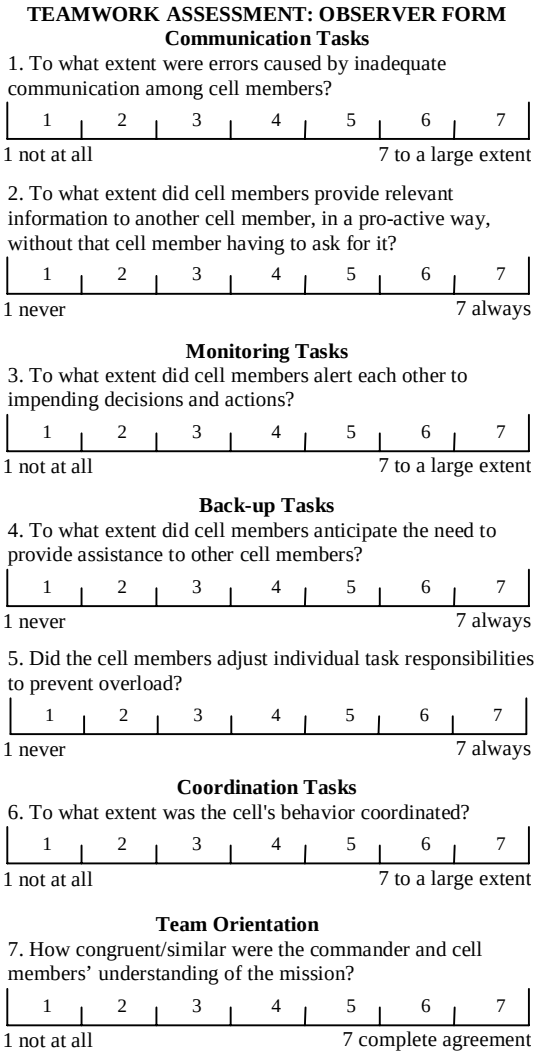

Figure 3-4. Questionnaire to Help in the Assessment of Teamwork

Collecting all of the communications intended to be captured on the collection form shown in Figures 3-2 through 3-4 proved to be more difficult than expected. As a consequence, multiple collection sheets were created by the AFRL/HEA C2TR team members throughout the JEFX spiral events in an attempt to improve and optimize the process for collecting the transmission of TCTC intra section and inter section communications.

The inability of the assessors to capture all of the operator communications was due to multiple factors. Limitations in data capture existed because of the inability to make use of the team's electronic data collection tools, limited access to the operator communications mediums (headsets, computer processor, or communications boxes), and

the restrictions caused by the team's reduced numbers and restricted physical location within the TCT Cell.

Figures 3-5 through 3-8 are samples of the revised collection sheets programmed for use during the Main Experiment. The main improvement to the new forms was the descriptive depiction of all the operators within each of the primary sections. This allowed for a more comprehensive capturing of where the majority of communications were taking place in each section. The reader should note that the form samples depicted in Figures 3-5 through 3-8 were actually printed on full-page collection sheets. The sample collection forms have been compressed for easy inclusion in this report.

Located at the bottom of each data collection sheet was a section reserved for the operators to record amplifying notes of events that occurred within the TCTC. Due to the high operations tempo within the TCTC, it was quickly discovered that it was a very challenging task to manually attempt to record the vast quantity and variety of communications taking place within each section. As a result, the AFRL/HEAI assessors tailored their data capture techniques to meet the requirements dictated by the operational nature of each section observed.

In addition to the other aspects of the collection forms discussed, at the very bottom of each data collection sheet was a key for identifying the different forms of communications that took place between the operators. The communications key allowed the assessors to simply record a single letter to indicate the specific type of communications exchange that occurred. This aided assessors in the reconstruction of events and provided additional insights into the manner in which operators were communicating.

The communications key included the following symbols:

A = for use of the **ACCESS** comm box employed for simulation/live communications

B = for the Theater Battle Management Core System (TBMCS) **Bulletin Board** function

C = for use of "**crib** sheets" or the passing of written notes to one another

D = for use of the Distributed Interactive Simulation (**DIS**) voice communication systems

F = for **face** to face or shoulder to shoulder communications

I = for use of the **Info**WorkSpace (IWS) collaborative tool

L = for use of the **Large** Screen Displays to communicate with others

N = for the Advanced Simulation Technology Incorporated (ASTI) internal communications **network** box

O = for **open** air, commonly referred to as "Net 4" or communications unaided with electronic devices

P = for use of the common tele**phone**

PA = for use of the **public address** system

R = for use of the ground-to-air **radios** to transmit or receive

S = for use of the "**sneaker** net", i.e., getting up from your operator position to communicate with someone else

T = for use of the IWS **text** function

The AFRL/HEAI recorders were furnished a headset and were free to observe all operations and displays. The Section leadership, personnel, civilian technicians, and other assessors were most helpful in clarifying the information recorded and offering explanations and expanding views to go with the information recorded.

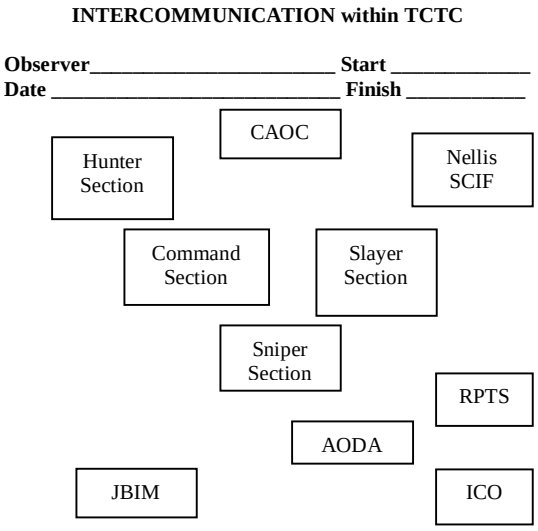

Figure 3-5. Layout of TCTC Team to Capture Team Interactions and Information Flow

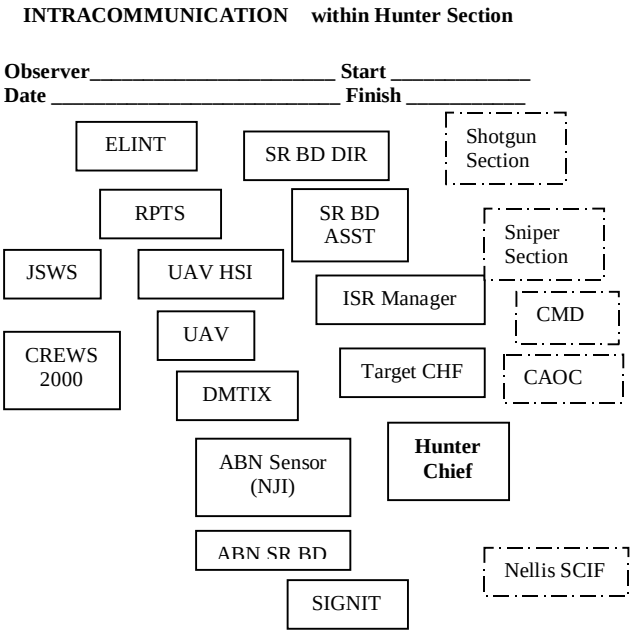

Figure 3-6. Layout of Hunter Section to Capture Team Interactions and Information Flow

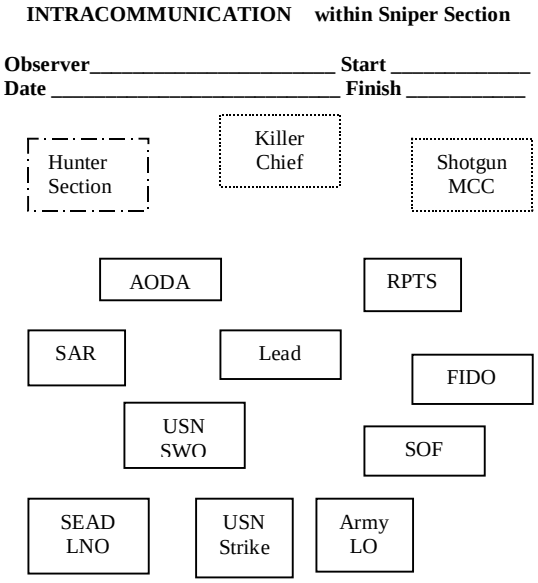

Figure 3-7. Layout of Sniper Section to Capture Team Interactions and Information Flow

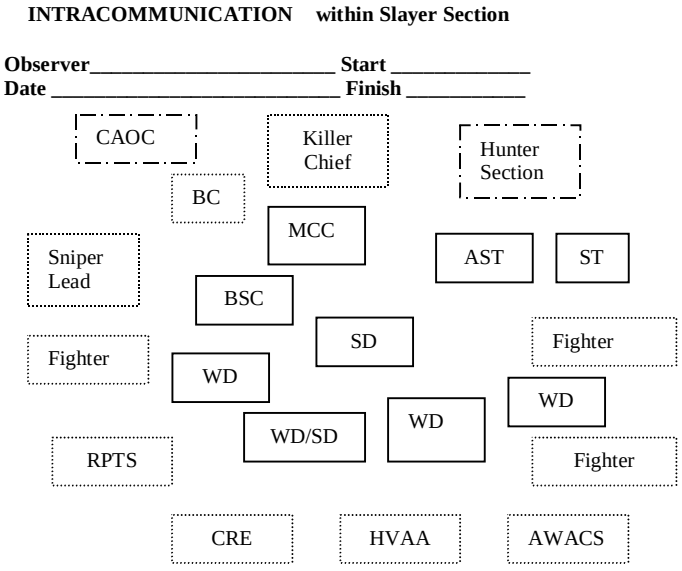

Figure 3-8. Layout of Shotgun Section to Capture Team Interactions and Information Flow

As mentioned previously, data collection during the main experiment proved to be somewhat difficult. This was especially true in situations where the assessor was without access to the operator's communication equipment. As a result, impromptu methods were used to capture as much of the activities occurring as possible. Many times the observers just quickly wrote down the communication chronologically in a log format, specifying the time for each communication, how the message was sent, who sent the message, and who received the message. Figure 3-9 highlights the complexity of capturing the myriad of communication sources and avenues that were in use during JEFX 00.

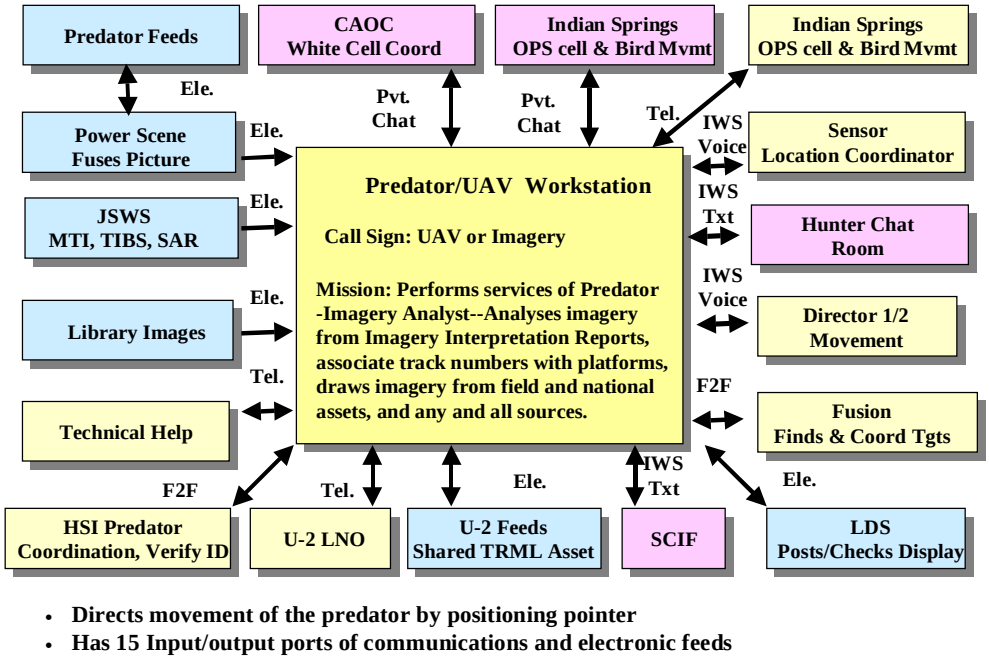

Figure 3-9. Example Predator/UAV Workstation Connectivity

Each communication was noted as either coming into the player position where the observer was collocated, or going out. It should be noted that the communications captured for other player positions, (i.e. Killer Lead) were only from the perspective of the player position in which the observer was collocated. The communications can really only be assessed with an observer collocated at the position in interest.

The communications were categorized in two ways. One categorization was the mode of communication used by the TCTC operator such as face-to-face, internal simulation networks, or UHF radio methods. Another categorization was the type of communication that took between the TCTC operators. The types of categorizations used to describe the types of communications between the TCTC operators include the following: (1) Requests for information (RFI); (2)

Coordination communications; (3) Directive Orders, (4) Information updates, or (5) Communication responses or confirmations

In the course of the spiral nature for improving the data capture methods, another form was developed to capture in an organized manner as much of the activities occurring as possible. From the experience gained during JEFX 00 Spirals 2 and 3, it became clear that the data capture process would require a form that was simple in design, yet formatted in such a way as to allow the comprehensive logging of desired information. Table 3-1 is an example of the form used.

Table 3-1. Example Communications Transmission Capture Form

Collector: _Garrambone____ Date___6 Sep 2000_ Start _1759_ End _2200___Page _1__of __8___

Cell/Section ____Hunter____ Physical Location __Director 1 corner_____ Episode___ Day 3_____

	Time Zulu	Mode Type	From	To	MSG Gist	RFI	Coor	Ord	Up Date	Res/ Conf
1.	1757	C	HL	All	Radio Check (All come up)	x				
2.		C	D2	All	Set up map—prepare symbology			x		
3.		C	HL	Tgt	Is your radio working					x
4.	1800	C	D1	SCIF	Is your radio working					x
5.		C	D2	All	Reporting downed crew member—CSAR Mission					x
6.	1801	C	Rvn	All	JSTAR in AO		x			
7.		C	D1	All	Focus on two possible targets			x		
8.	1802	C	D2	Sen	Provide ISR asset status check	x				
9.		C	JBIM	D1	Radio check		x			
10.	1803	F	HL	BDA	Coordination		x			
11.		**F**	D2	D1	Note 4 targets on screen—remove these two				x	
12.	1804	C	D1	Img	Are these tgts from yesterday?	x				
13.		F	HL	TCTC	Coordination					
14.		**F**	D2	D1	Showing too much detail in grid box		x			
15.	1807	C	D1	HL	Too much detail and indistinguishable colors		x			
16.		C	Rvn	D2	I've determined tracks on two tgts				x	
17.	1808	C	Fus	D2	Screen clears when transition takes place		x			
18.	1809	C	Sen	HL	Provide information	x				
19.		F	HL	Sen	Coordinating information		x			
20.		C	D2	D1	Status of SA-10 in listing column of data?	x				
21.	1810	C	D1	JBIM	Proper info on screen being worked					x
22.		C	JBIM	D1	Need RICO help		x			
23.	1811	C	Sen	D1	Coordinate on visual tgts		x			
24.	1812	C	D2	All	Use filters to clear screen clutter		x			
25.		C	D2	Fus	Did you copy this?	x				
26.	1813	F	D2	Tgt	Filter use discussion		x			

R = Radio Trans/Rec	B = IWS BBS	F = Face-to-Face	Ord = Order
L = Large Screen Display	A = IWS Audio	P = Person-to-Person	Res/Conf = Response/Confirmation
D = DIS Net	T = IWX Text	S = Sneaker Net	RFI = Req for Information
T = Telephone	C = 16 channel phone	PA = Public Address	CB = Crib sheet

As a result of the plethora communications captured and the observation of all TCTC activities, data was captured that allowed analysts to produce workload/targetload charts analogous to the one depicted in Figure 3-10. This type of data is useful for tracking all TCTC target category lists, e.g. Emerging Targets and Designated Targets. This could be used as a barometer for the human operator work/stress levels and overall TCTC activity. It could be a useful leadership and manpower utilization management tool and could potentially be projected onto the Large Screen Display during TCTC operations.

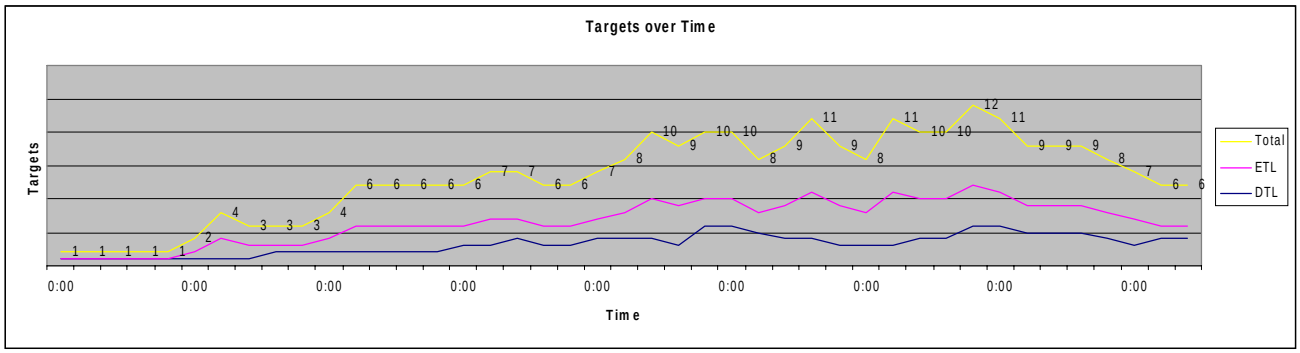

Figure 3-10. Sample TCTC Target Load Over Time

3.5 Approach to the Team Leadership Assessment

It was predicted early in the assessment planning process that leadership, something that no previous JEFX had addressed, would be a key factor in the successful operation of the experimental TCT Cell. This hypothesis was the foundation of this analysis and was found to be absolutely true. This section describes the circumstances and setting for the experiment, the measures of merit and the results of watching, listening and gather evidence. It was found that the individuals chosen as TCT Cell leaders provided the interpersonal, conceptual, technical and tactical skills needed to focus team purpose, provide coordinated direction and produce overall group motivation to accomplish the mission. In all, the TCTC leadership's displayed all the Air Force values and demonstrated warfighting staff planning competencies.

AFRL/HEAI analysts devised an assessment plan to identify and report on the forms/demonstrations of leadership which were necessary to create a successful and functioning, environment for accomplishing the time critical targeting cell mission from an eclectic group of commanders, operators, staff officers, mission planners and highly technical communications, electronic, and intelligence specialists. By all standards, this organization was a "work-in-progress" operation of individuals learning to create operational procedures and using newly acquired and previously untried equipment. The goal of the assessment was to identify the leadership requirement needed to create a team to detect, decide, devise, and destroy targets.

3.6 Design of Leadership Assessment

In order to efficiently capture information about leadership, it was necessary to characterize military leadership into a "schema" for leadership identification. Next, because of the number of individuals involved in the TCTC, it became necessary to identify the particular individuals to observe exercising leadership. For collection purposes it was also necessary to create the data tables needed to record the key information which captured the instances where

this leadership was being demonstrated. These tasks were begun by identifying the areas that represented leadership using the information derived from multi-service military references and next by identifying those positions within the TCTC for which responsibilities were assigned or delegated. The next part of the task was to note the environment and circumstances, and to collect, in written form, those demonstrated attitudes, deliberate and aside statements, and most importantly the actions which guided the behavior or opinion of others and directed their performance or activities toward achieving certain goals or results. With these collections of attitude, words, and actions the next step would be the proper categorizing and reviewing of the information for analysis and reporting.

3.7 Measures of Merit

Leadership was looked at from a design matrix of four dimensions (values, attributes, skills, and actions) in 17 leader-specific categories. We sought to define each of the categories and to create a means to identify instances of demonstrated leadership by individual's comments, by their representations of operational knowledge, and by the manner in which they took action to motivate and lead their parts of the organization. Table 3-2 represents the schema used for looking at leadership and formed the measures of merit in judging examples to validate the hypothesis.

Table 3-2. Leadership Categories

JEFX 00 Leadership Schema (Four Dimensions)			
Values (7)	Attributes (3)	Skills (4)	Actions (3)
C01 Loyalty	C08 Mental	C11 Interpersonal	C15 Influencing
C02 Duty	C09 Physical	C12 Conceptual	C16 Operating
C03 Respect	C10 Emotional	C13 Technical	C17 Improving
C04 Self-service		C14 Tactical	
C05 Honor			
C06 Integrity			
C07 Personal courage			

3.8 Identification of the Specific Leaders to Observe

Although the TCT Cell contained many leaders and leadership examples at every level, the following chart indicates those leadership positions that received primary attention. It is important to note that the Hunter Section had a director lead, a target lead and a fusion lead, and the Killer Section had a mission planner lead (Sniper), mission control lead (Slayer) and a weapons director (weapons portion of the Slayer team). Figure 3-11 outlines the positions observed in the leadership assessment.

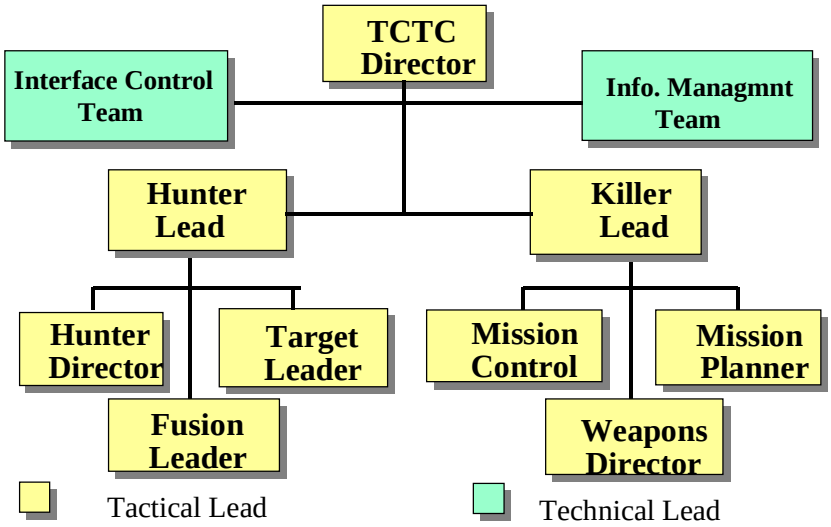

Figure 3-11. TCTC Principal Leadership Schema

A very specific rationale was developed for the selection and comments about each of the positions identified. In all cases, the comments collected were made by individuals who will not be identified by name or gender in this report. AFRL/HEAI is prohibited from reporting any JEFX 00 results until the AFEO staff has out-briefed the Chief of Staff of the Air Force. JEFX 00 was an experiment, which shows only feasibility. It is important for the reader to take note of the fact that assessment procedures must be examined in a laboratory environment, which takes into consideration all the variables that were not controlled in order to show improvement and establish causality.

SECTION 4.0
SUMMARY

4.1 Summary Thoughts

The human operator is a critical link in the effective functioning of command and control operation centers. Modern C2 centers have incorporated ever increasing advances in warfighting technology that spans the man-machine-interface continuum of operator displays, decision aides computing systems, precision location processes, and complex and sophisticated data link communications. JEFX 00 provided AFRL/HEAI analysts with an excellent environment in which to gain insight into the implications these modern technological advances and changing concepts of operations pose for the human element.

Under the circumstances afforded the AFRL/HEAI analyst, considerable amounts of data were collected to allow for substantive assessments to be made of the many factors that can effect the functioning of the modern C2 warfighter. Although the results of the AFRL/HEAI assessments cannot be publicly shared at this time, valuable information was, in fact, derived from JEFX 00 that begins to help characterize C2 operator workloads, cognitive loads, individual and team processes, critical information flow, decision making, communication patterns, and the important dynamics and impact of leadership.

4.2 Significance of Leadership

The nature of experimentation is quite different from that of a traditional Air Force exercise or contingency operation and JEFX 00 included many frustrations and challenges that tested the professionalism and endurance of the TCTC personnel. Strong, "hands-on" leadership was needed to maintain the intensity of the operations and keep the operators focused – especially during the idiosyncrasies of distributed simulation and the tightly controlled peacetime live-flying operations.

Leadership was the most important factor in the success of the TCT Cell. Generally speaking the TCTC leaders scored high in all 17 leadership categories and affected every aspect of the TCTC operation. They provided the interpersonal, conceptual, technical, and tactical skills needed to focus the team, provided coordinated direction, and produced overall group motivation to accomplish the mission.

Because the TCTC decision-makers were teamed directly with the supporting information providers, the collective TCTC organization was able to effectively accomplish the C2 decision making process for time-critical targeting. In addition, the assessment team was able to devise and capture, for analysis, the activities and efforts required to connect the "sensor-to-shooter" operating mechanisms and to display this functionally using descriptive measures useful to the warfighter.

Analysis of the communications network was the key to assessing the organization, its structure, the personnel and system requirements, and the training needed to measure and accomplish the mission. The communications network was the circulatory design of the operation and the information was the pulse. Measurements of the communications network and its operation showed it to be more extensive and more critical than previously imagined. The communications nets contained all forms of voice, text-based, imagery, and electronic information and were supplemented by direct voice communications and face-to-face discussions. The data contained in this report reflects the extensive communications that took place in order to prosecute time-sensitive targets.

The outcome of the analysis of the operator communications supported the TCTC leadership's direction to constantly push information up stream. The full cycle of battle management was supported in a single location, which facilitated an iterative feedback loop within the TCTC organization. Conversations on the internal links between the various section leads resulted in a better decision making process and, in-turn, better weapon solutions. The resident expertise on targets, weapons, and assets was distributed across the organization and the exchange of this critical data served to integrate knowledge and improve overall TCT process outcomes.

The process of capturing this assessment information, along with further analysis of the data collected, makes it possible to examine the TCTC operation in a warfighter laboratory environment where processes and systems can be closely examined and optimized. The information contained in the AFRL/HEAI's "JEFX 2000 Time Critical Targeting Cell Process Initiative Report" contains a lot of observed data that will be useful to the warfighter, the C2 operational community, and will provide the basis for further research and designs for required C2 assessment and training.

The TCTC Process Initiative, as executed during JEFX 00, should be comprehensively analyzed and further refined. There is a clear military necessity for having a well-trained cadre of personnel capable of dynamically and efficiently responding to time sensitive and critical targets. In order to meet this goal with the correct type and mixture of human operators, a more detailed analysis of the micro and macro processes, communication patterns, and team interactions required within the TCTC needs to occur.